Adaptation to Climate Change Impacts on Water Resources:
A case study of the Merced River Basin

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Outline

- Background/Motivation
- Approach
- Results
- Conclusions

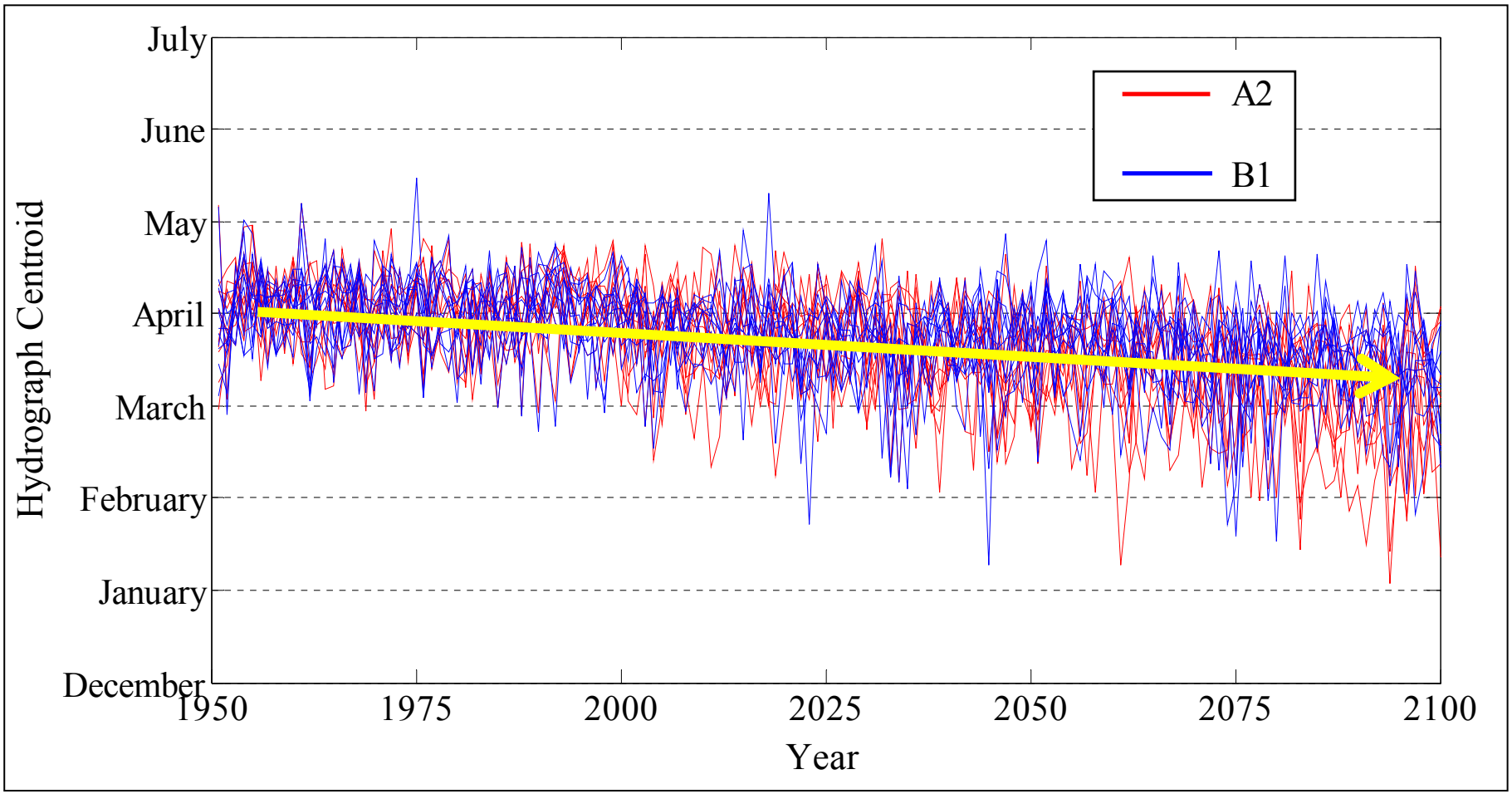
Background/Motivation

- Climate change impacts in California, summary:
  - Consistent effects: Earlier flows due to increase in temperature

- Climate change impacts in California:
  - Change in timing of streamflows

Timeseries of hydrograph centroid

(Merced River at Lk. McClure)

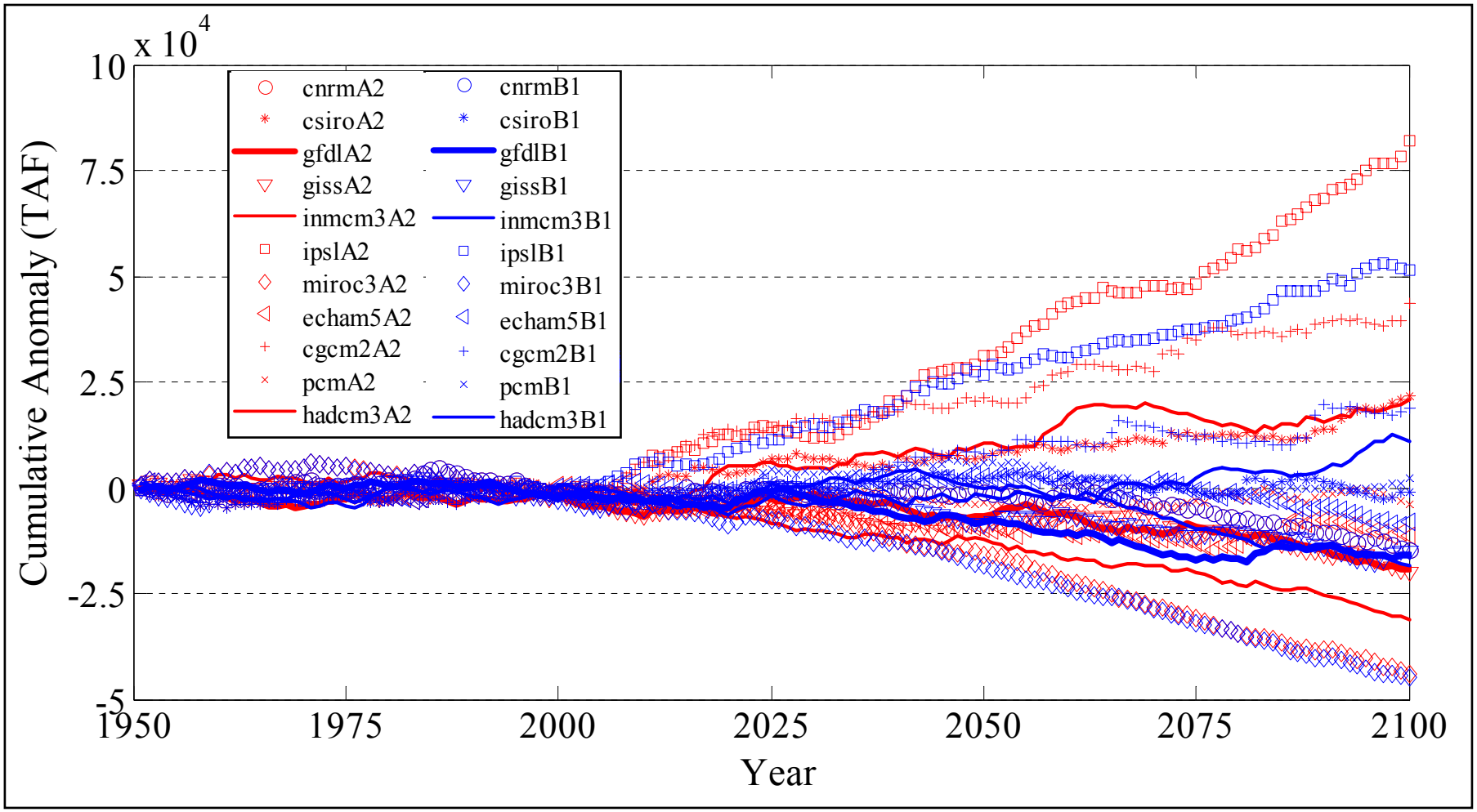


Background/Motivation

- Climate change impacts in California, summary:
  - Consistent effects: Earlier flows due to increase in temperature
  - Possible effects: increase in variability in annual inflows
  - Uncertainty effects: changes in annual precipitation/inflows, drier or wetter?

- Climate change impacts in California:
  - Uncertainty in annual inflows

    Annual Cumulative Inflows (Merced River at Lk. McClure)



Research questions

- Are there any “robust” policies that could be used to mitigate climate change impacts?
- Alternatives:
  - Reservoir re-operation (e.g. flood control rules)
  - New or modified Infrastructure
  - Conjunctive use of surface and groundwater

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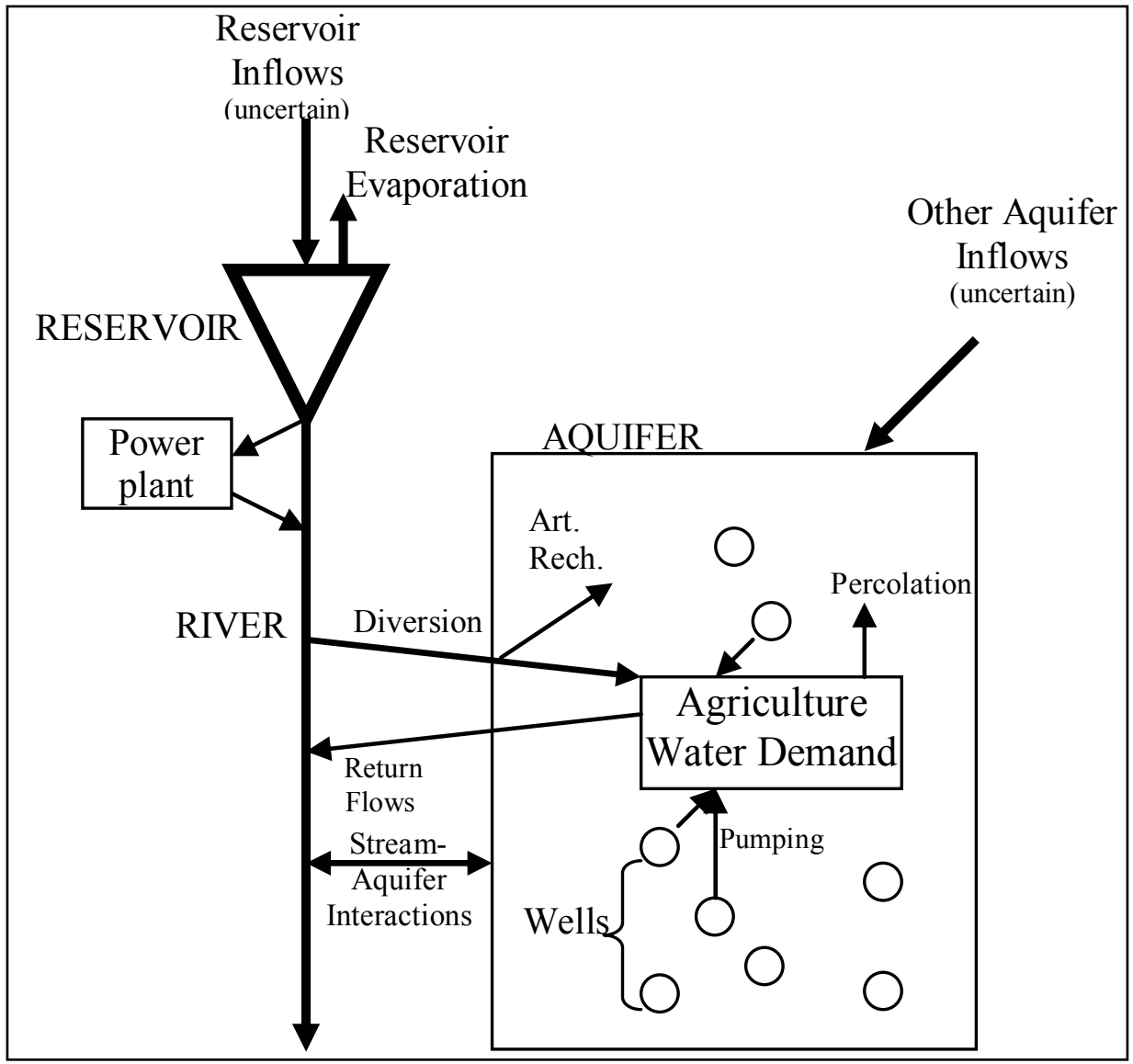
Basic conjunctive system representation



Approach

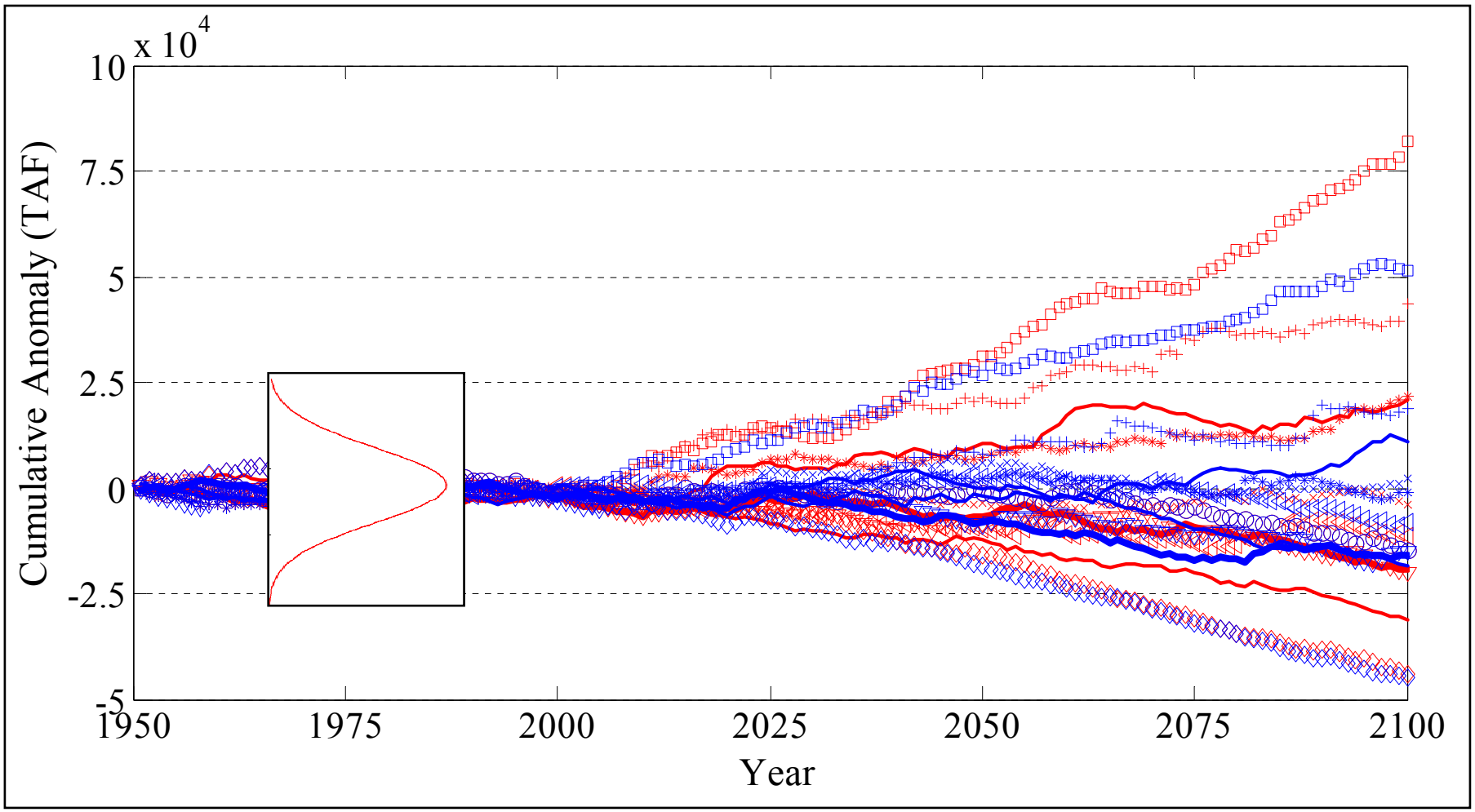
- Water resources optimization: how should a basin scale be operated under climate change scenario
- Complexities of Problem Formulation:
  - Non-linear (in objective function and system dynamics)
  - Includes stochastic variables (natural variability and climate change scenarios)
- A popular approach to deal with these complexities is Stochastic Dynamic Programming

Approach (part 2)

- SDP however assumes stationary hydrologic conditions (clearly not the case for climate change)
- Solution:
  - Use Annual Sampling Stochastic Dynamic Programming (*Kelman et al., 1990; Faber and Stedinger, 2001*) with monthly Non-Linear Programming model embedded
  - Uncertainty is not between probabilistic inflow classes (e.g. low-medium-large) but between intact hydrologic scenarios

Sampling SDP and climate change

Transition between climate change scenarios



Sampling SDP and climate change

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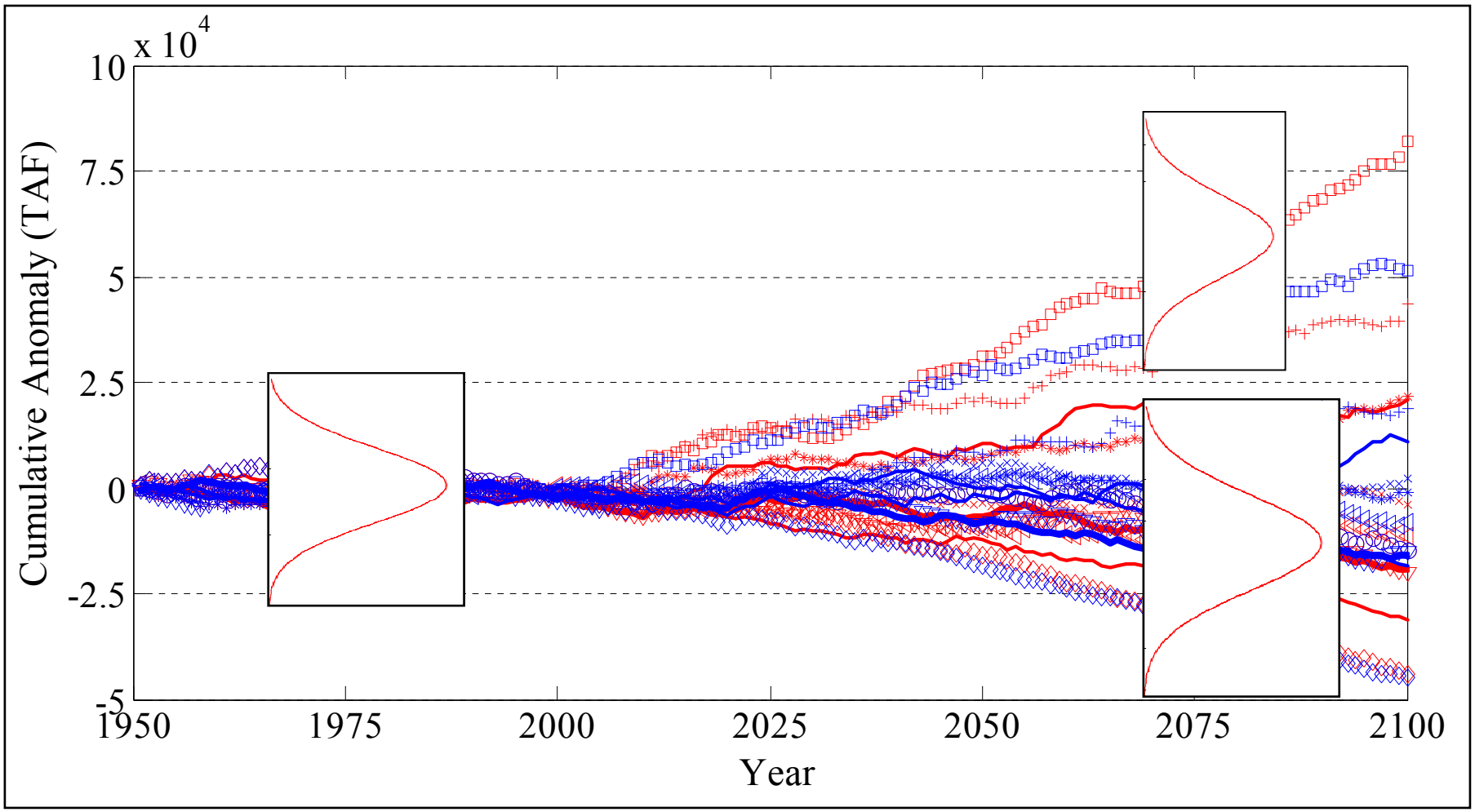

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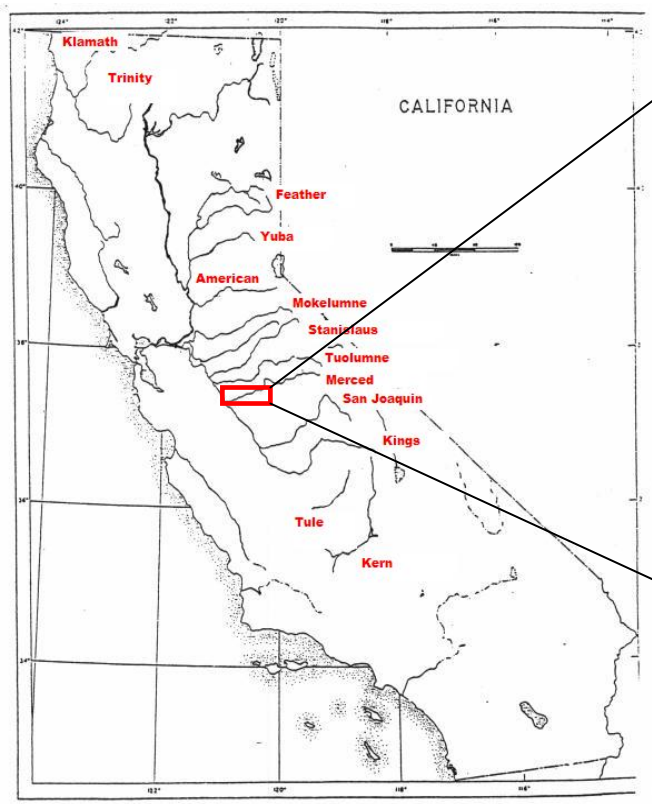
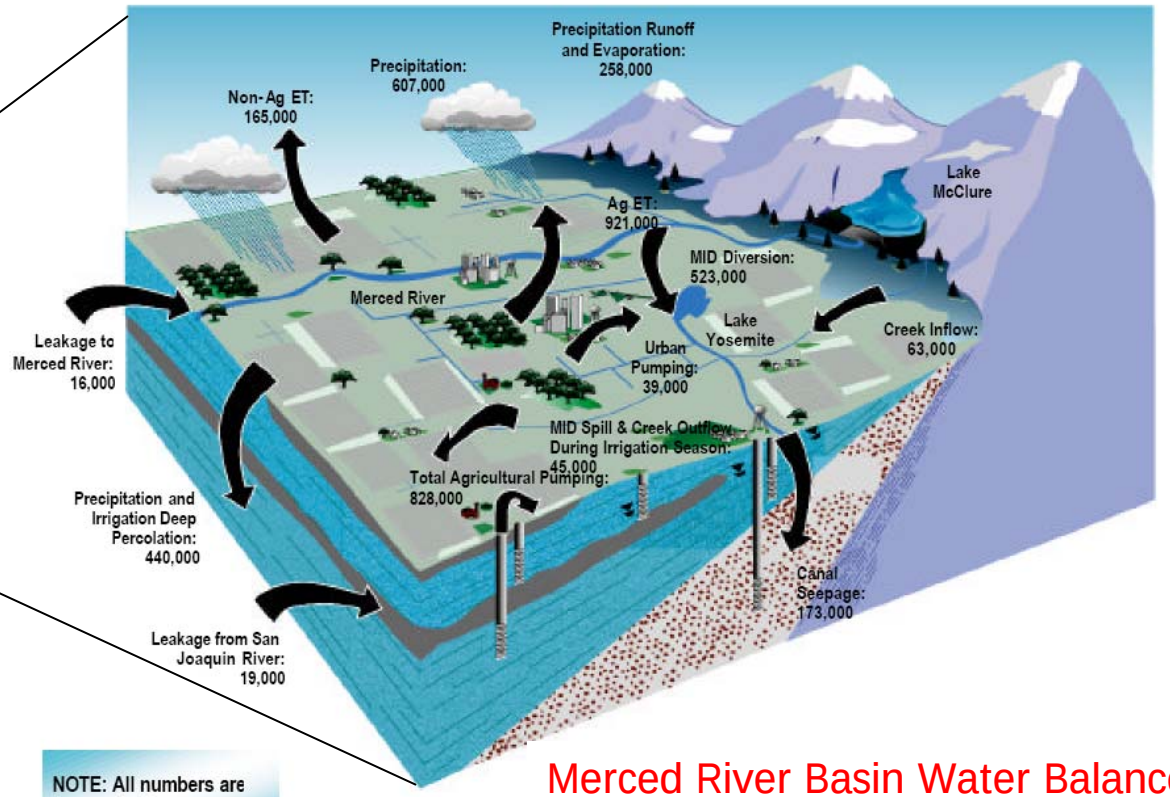
Case Study: Merced River Basin



http://faculty.sierracollege.edu/ccox/images/maps/CA_rivers_map.jpg



NOTE: All numbers are in acre-feet/year

Merced River Basin Water Balance

Merced Water Supply Update, 2001

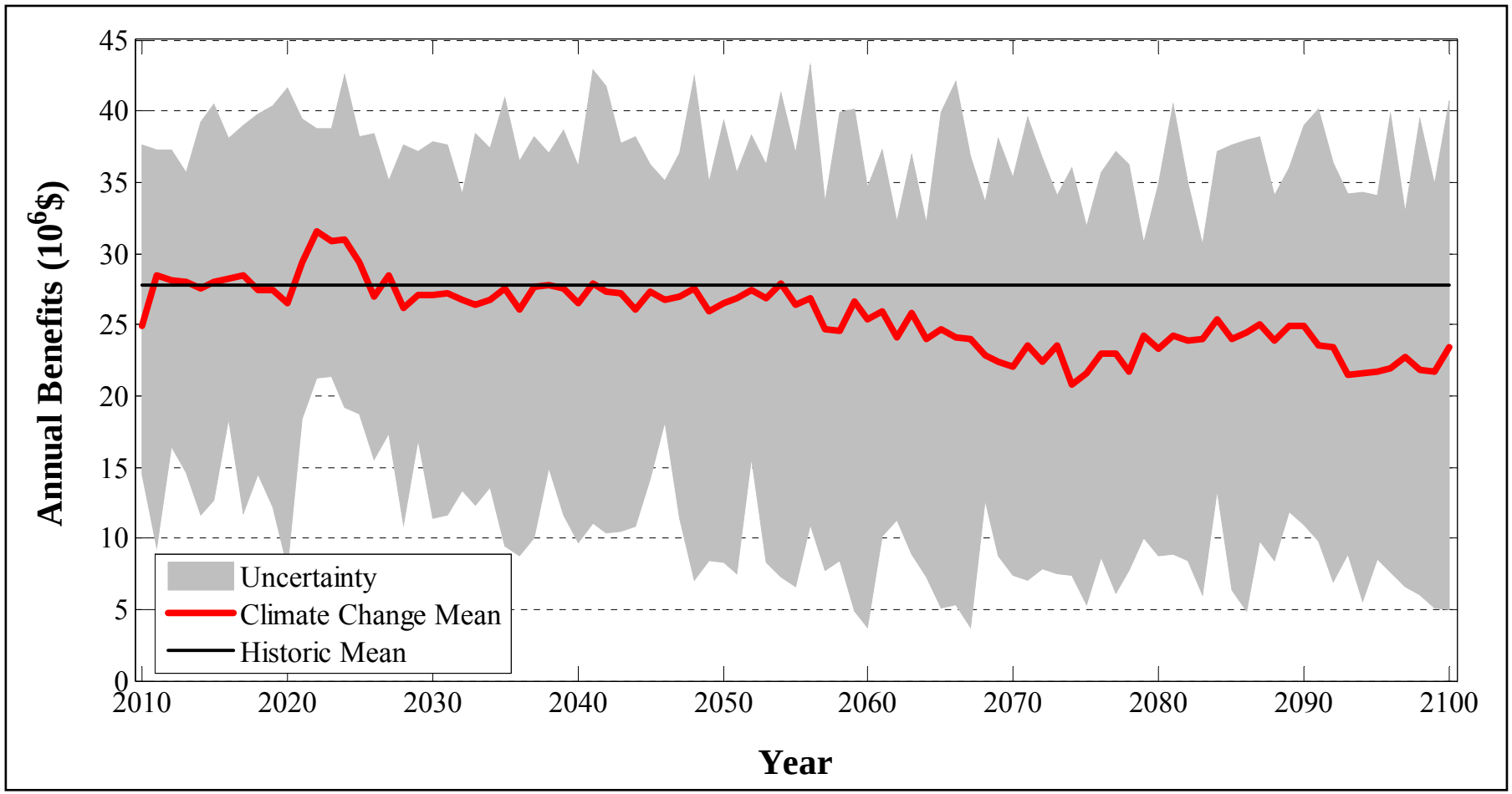
Results

- Case Study: Merced River Basin
  - Optimization/Simulation under climate change conditions w/o adaptation
  - Inclusion of adaptation strategies

Results

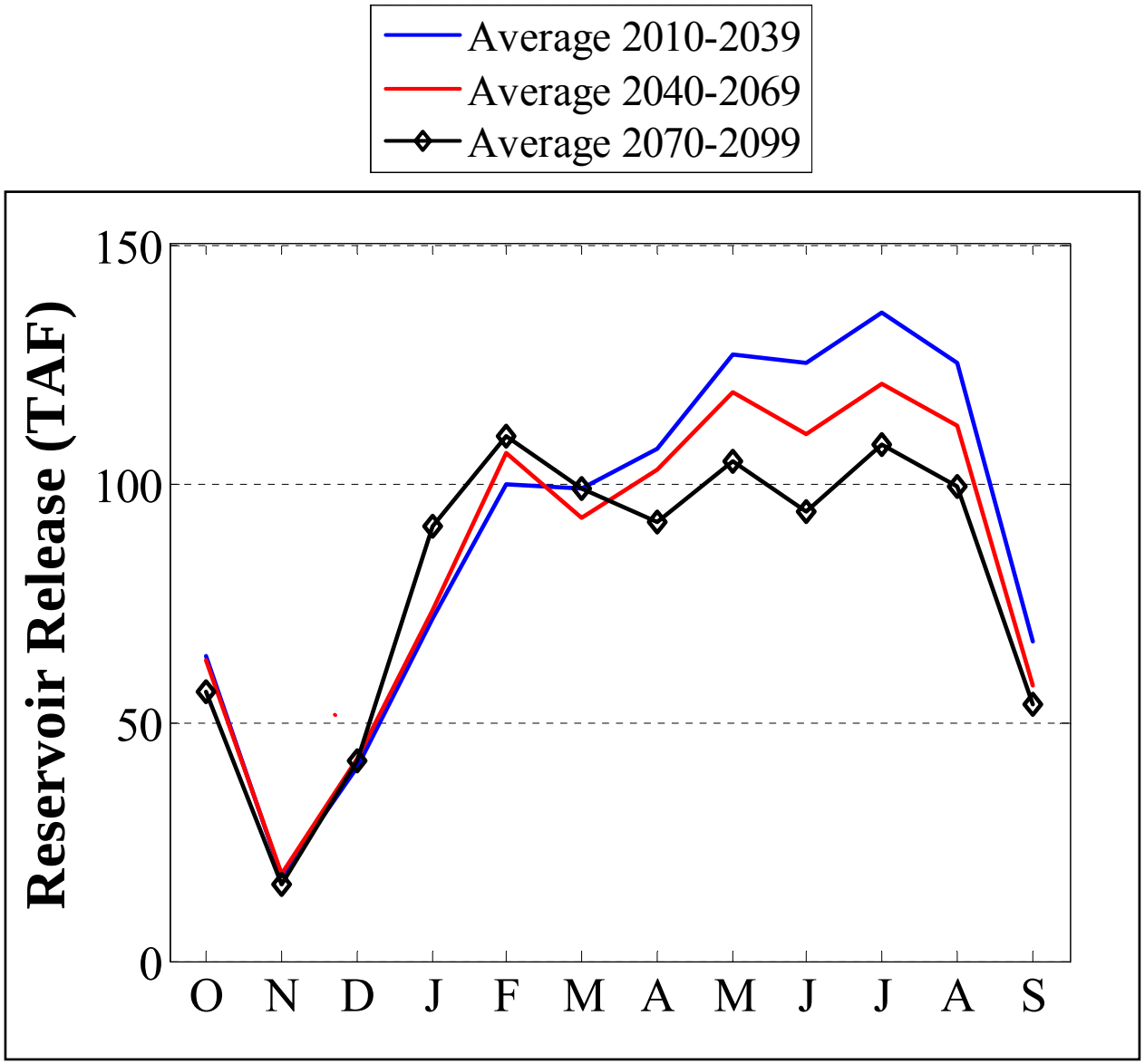
Base Case: Climate Change conditions

Annual Benefits time series



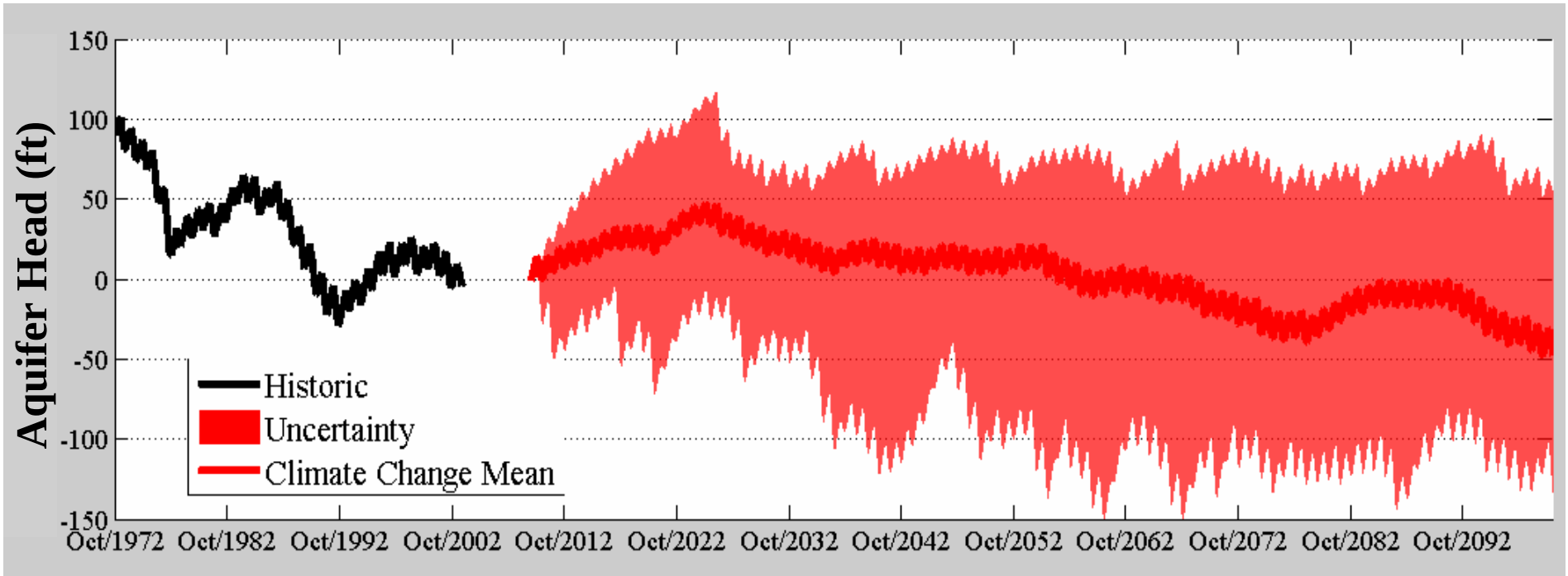
Base Case: Climate Change conditions

System Operations



Base Case: Climate Change conditions

Groundwater Levels

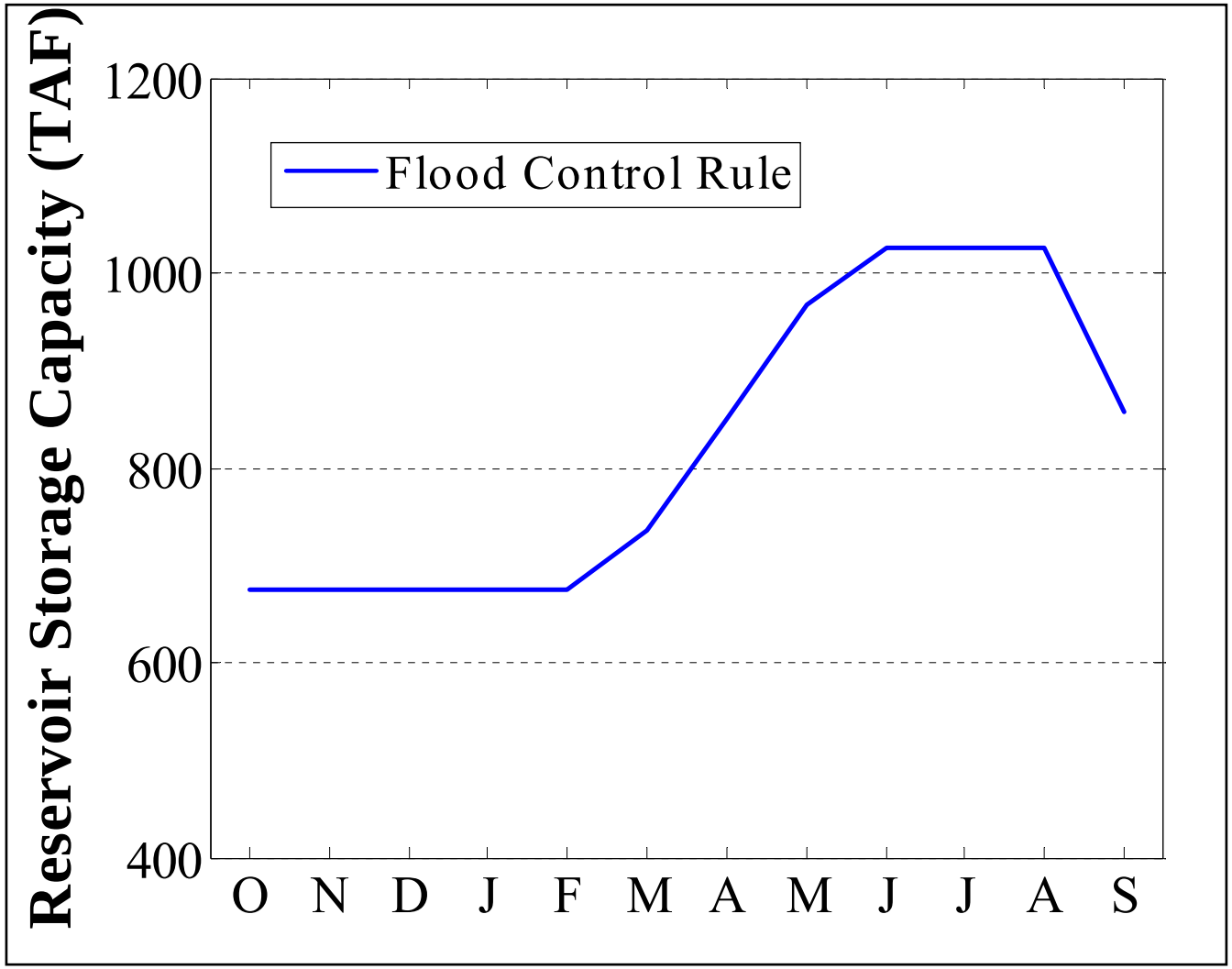


Results

- Case Study Development: Merced River Basin
  - Optimization/Simulation under climate change conditions w/o adaptation
  - Inclusion of adaptation strategies

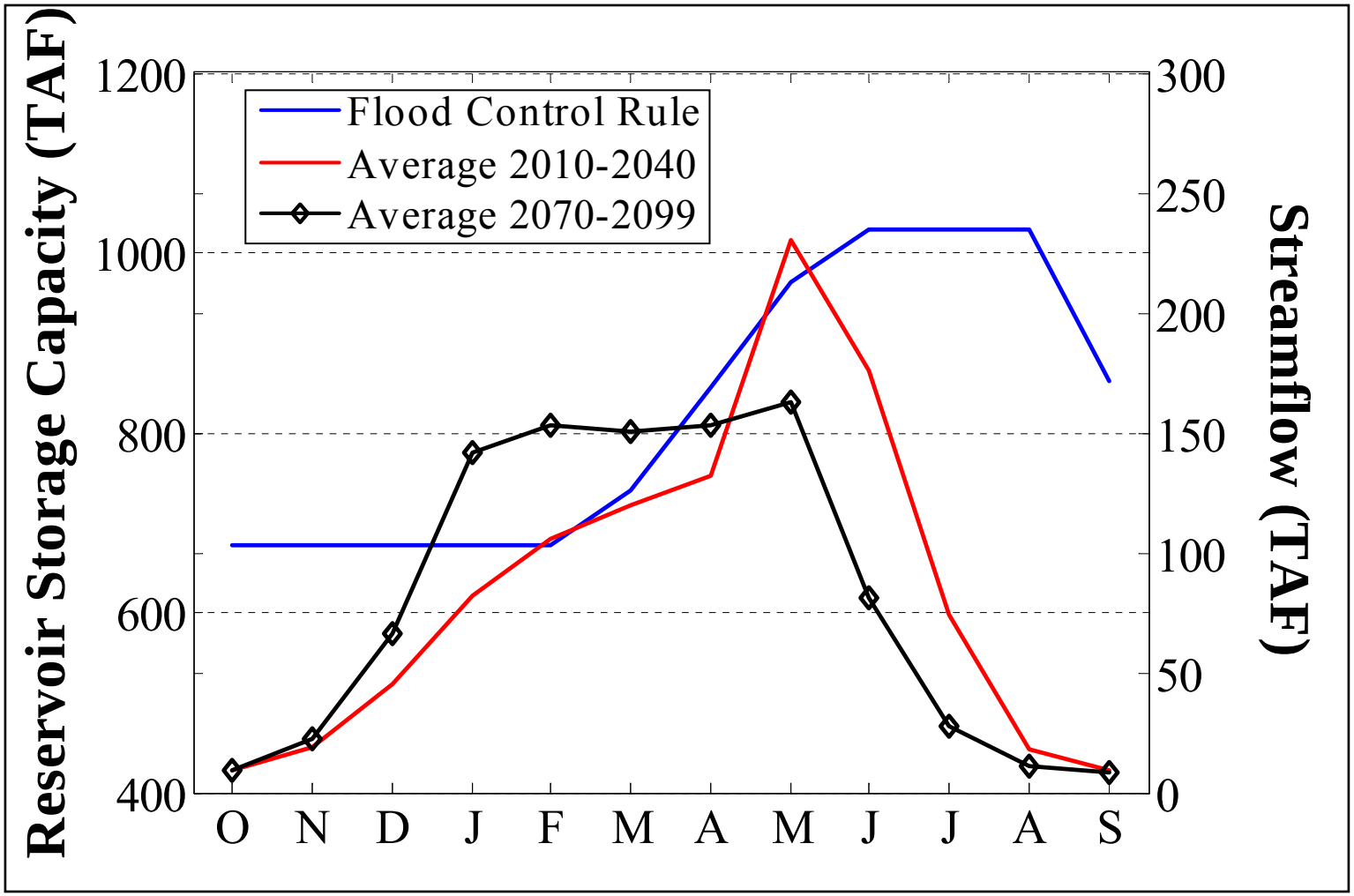
Adaptation Strategies:

Reservoir reoperation



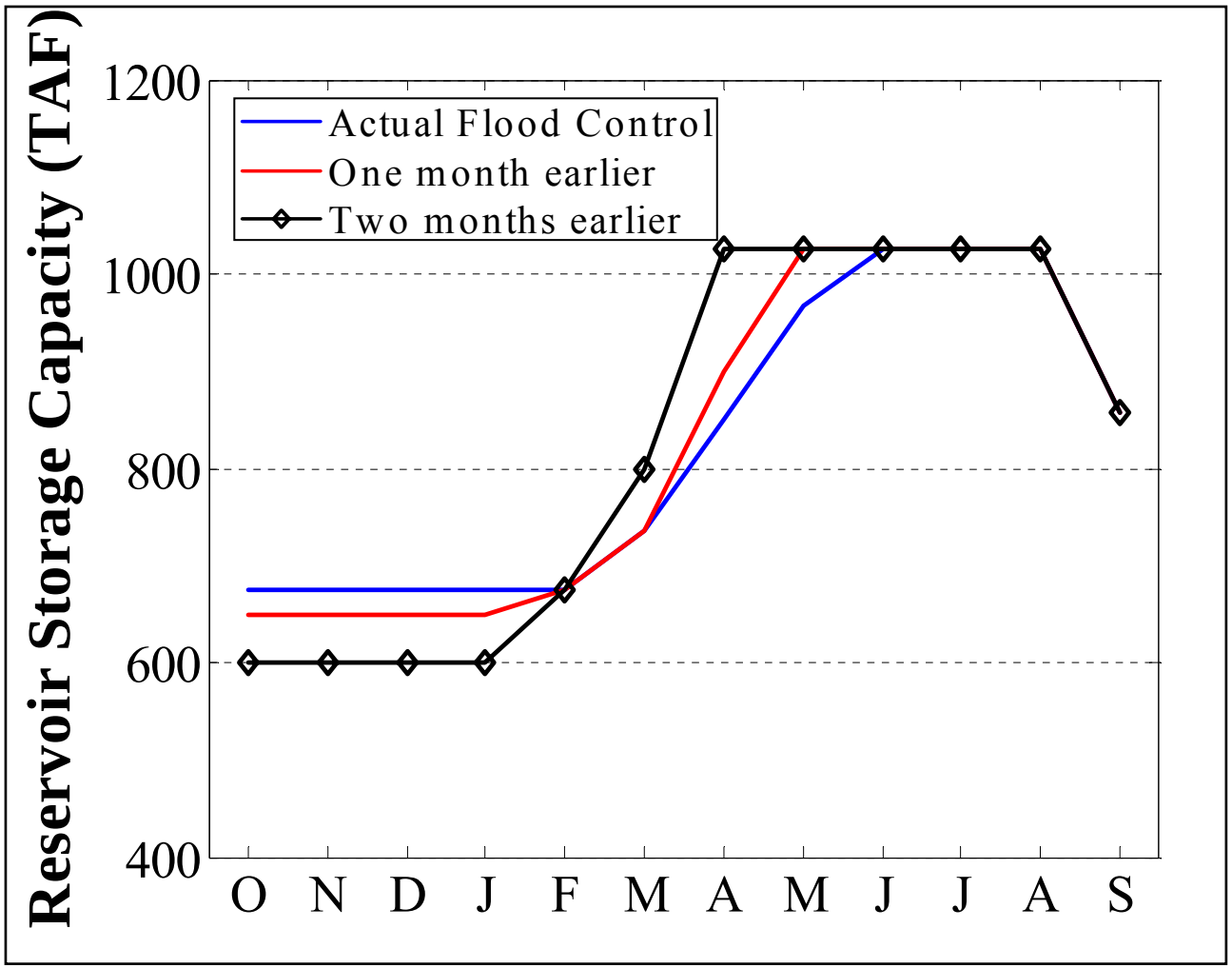
Adaptation Strategies:

Reservoir reoperation



Adaptation Strategies:

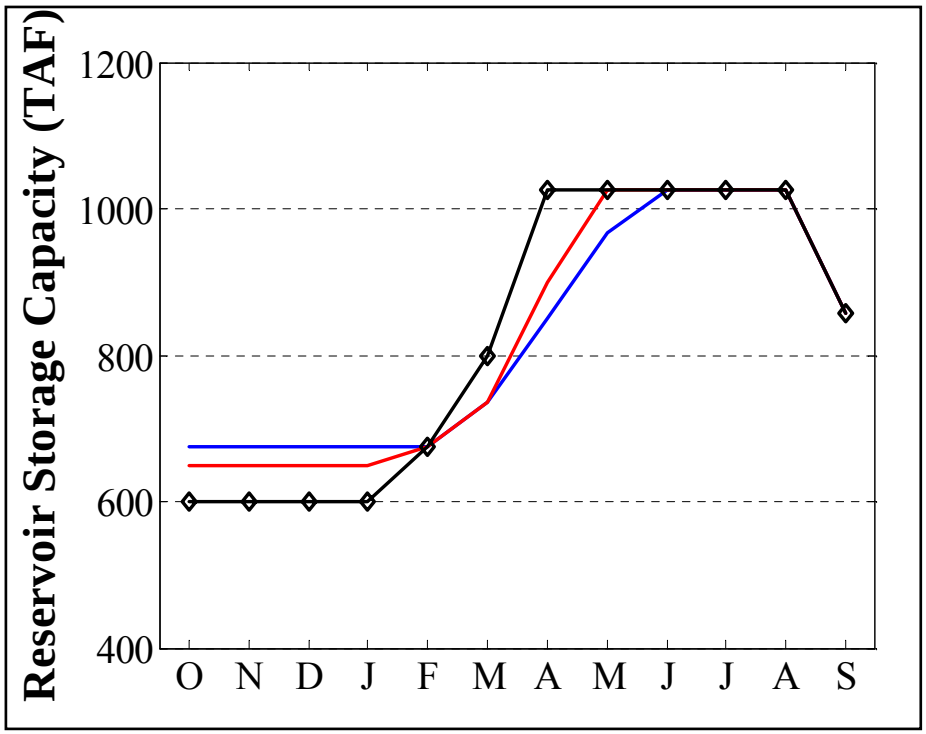
Reservoir reoperation

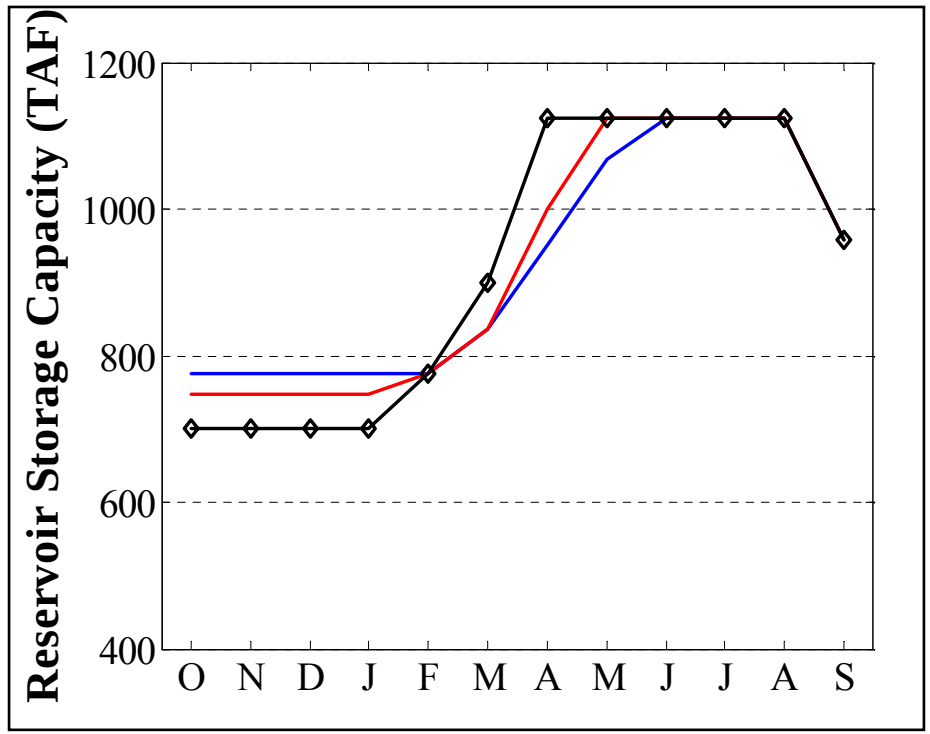


Adaptation Strategies:

Reservoir reoperation and Modified infrastructure

Higher Storage capacity





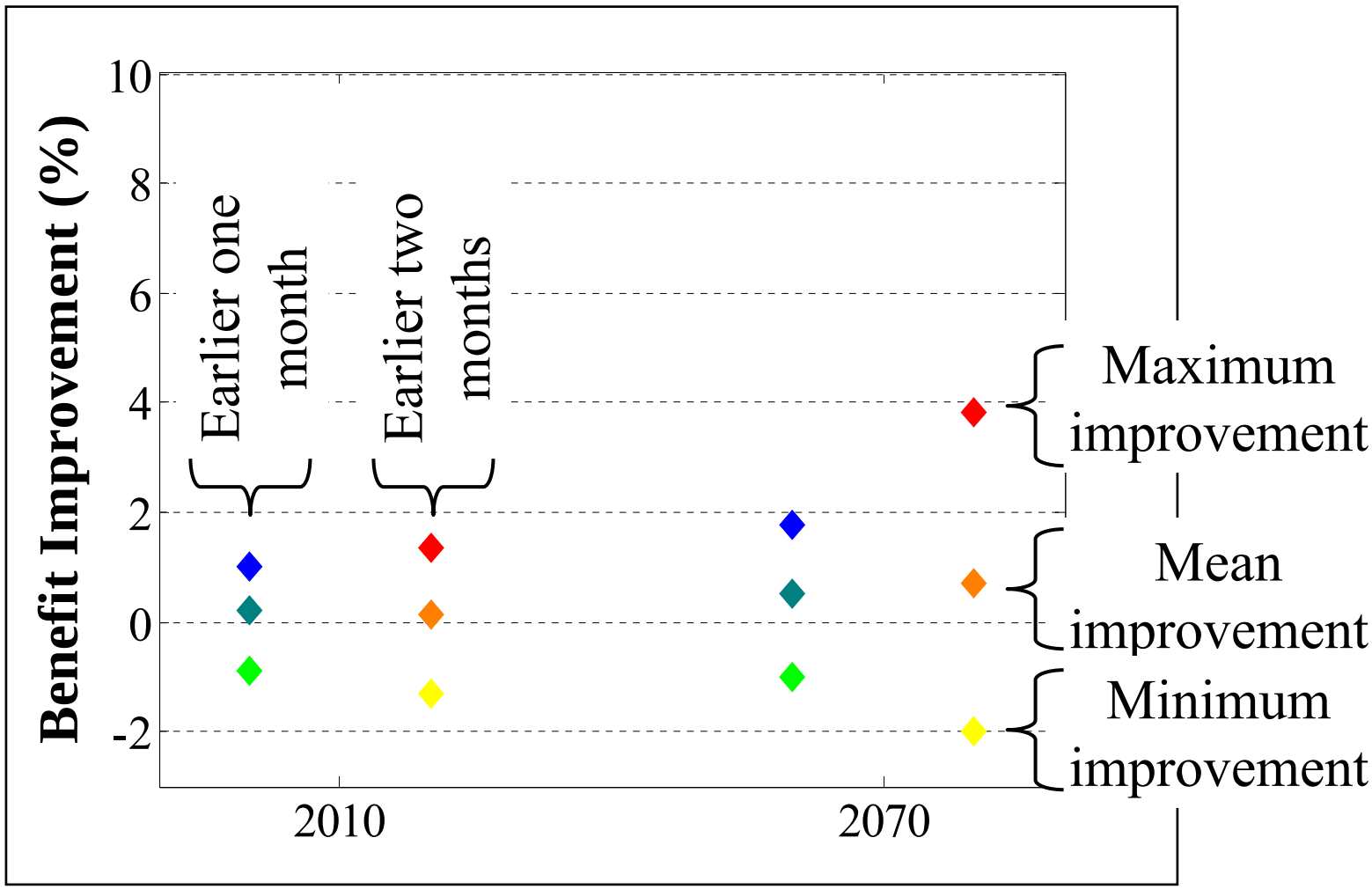
Actual Flood Control
One month earlier
Two months earlier

The strategy could be implemented at any of a set of given years: 2010, 2040 or 2070

Comparison between base case and adaptation scenarios

(1% change ≈ 2-3 10^6\$)

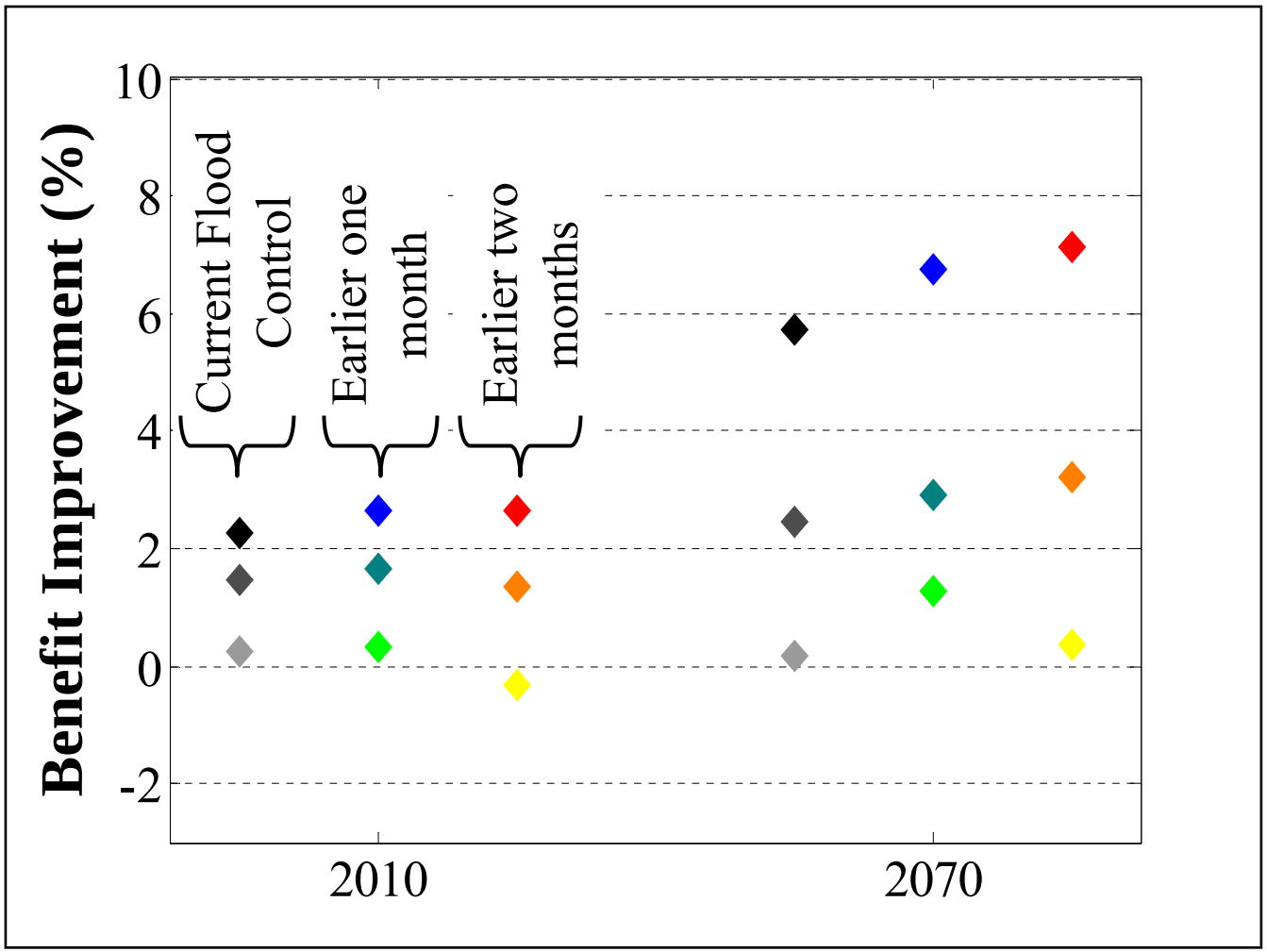
No Change in Storage Capacity



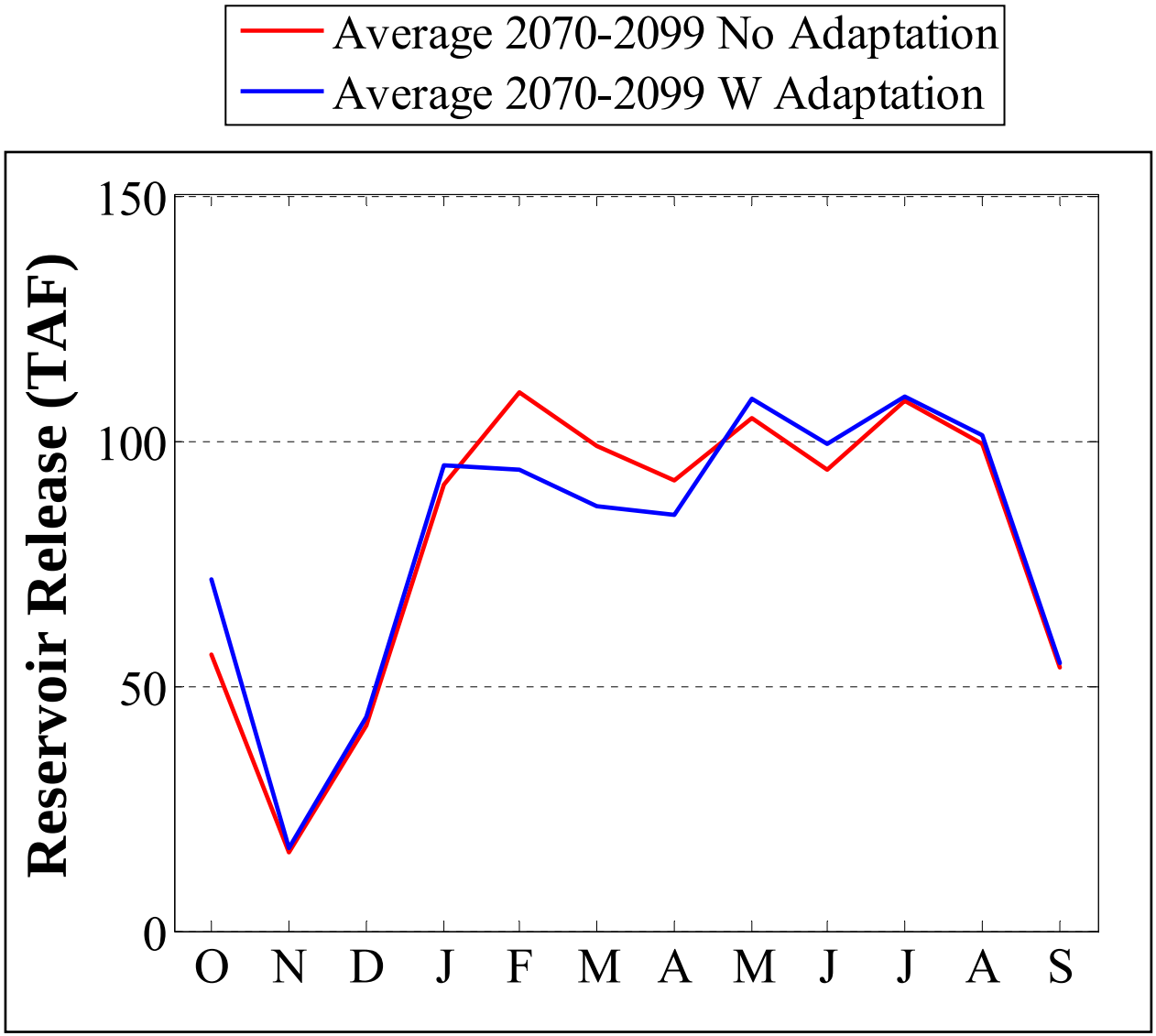
Comparison between base case and adaptation scenarios

(1% change ≈ 2-3 10^6\$)

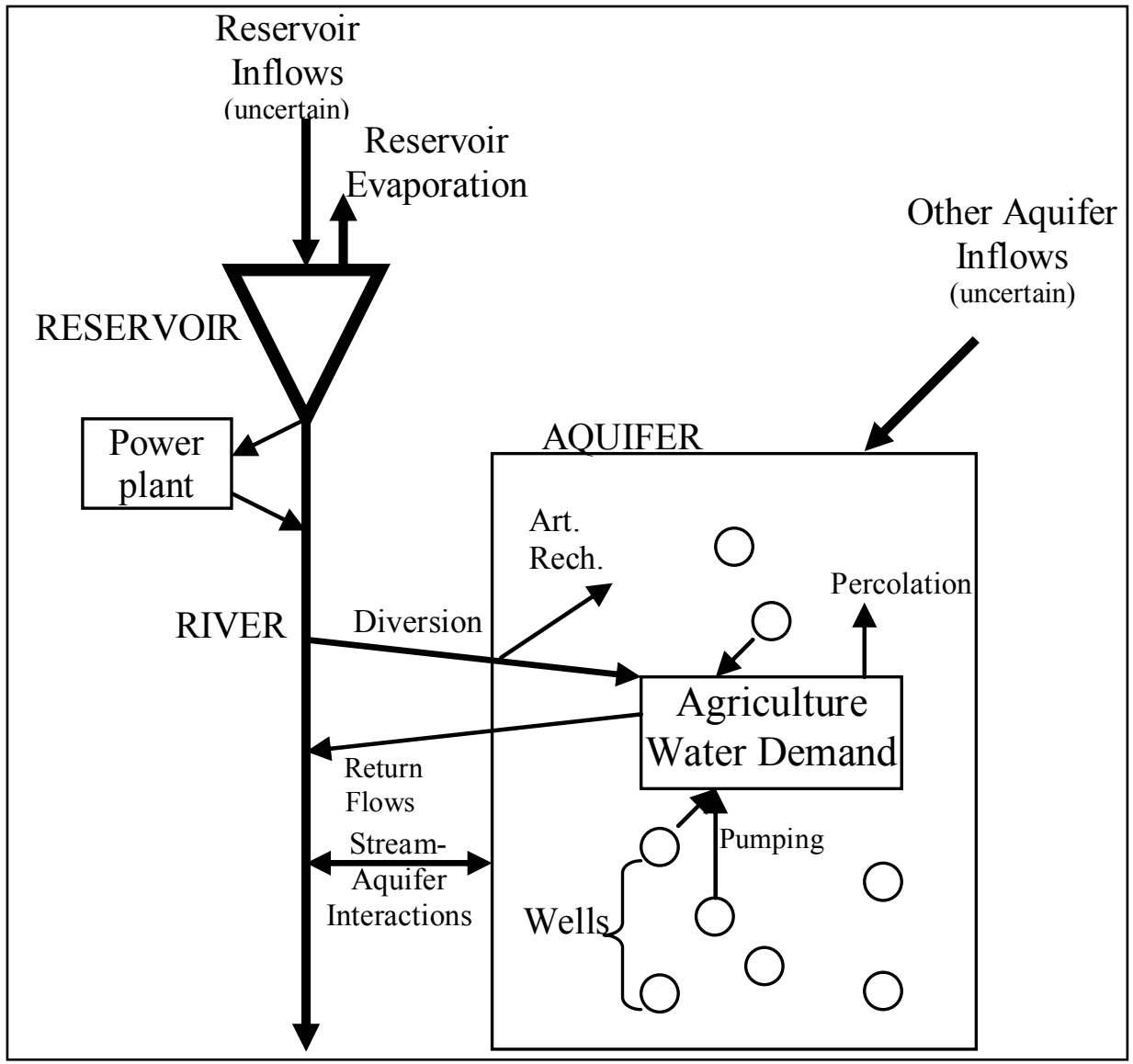
With a Change in Storage Capacity



Comparison between base case and adaptation scenarios: System operations

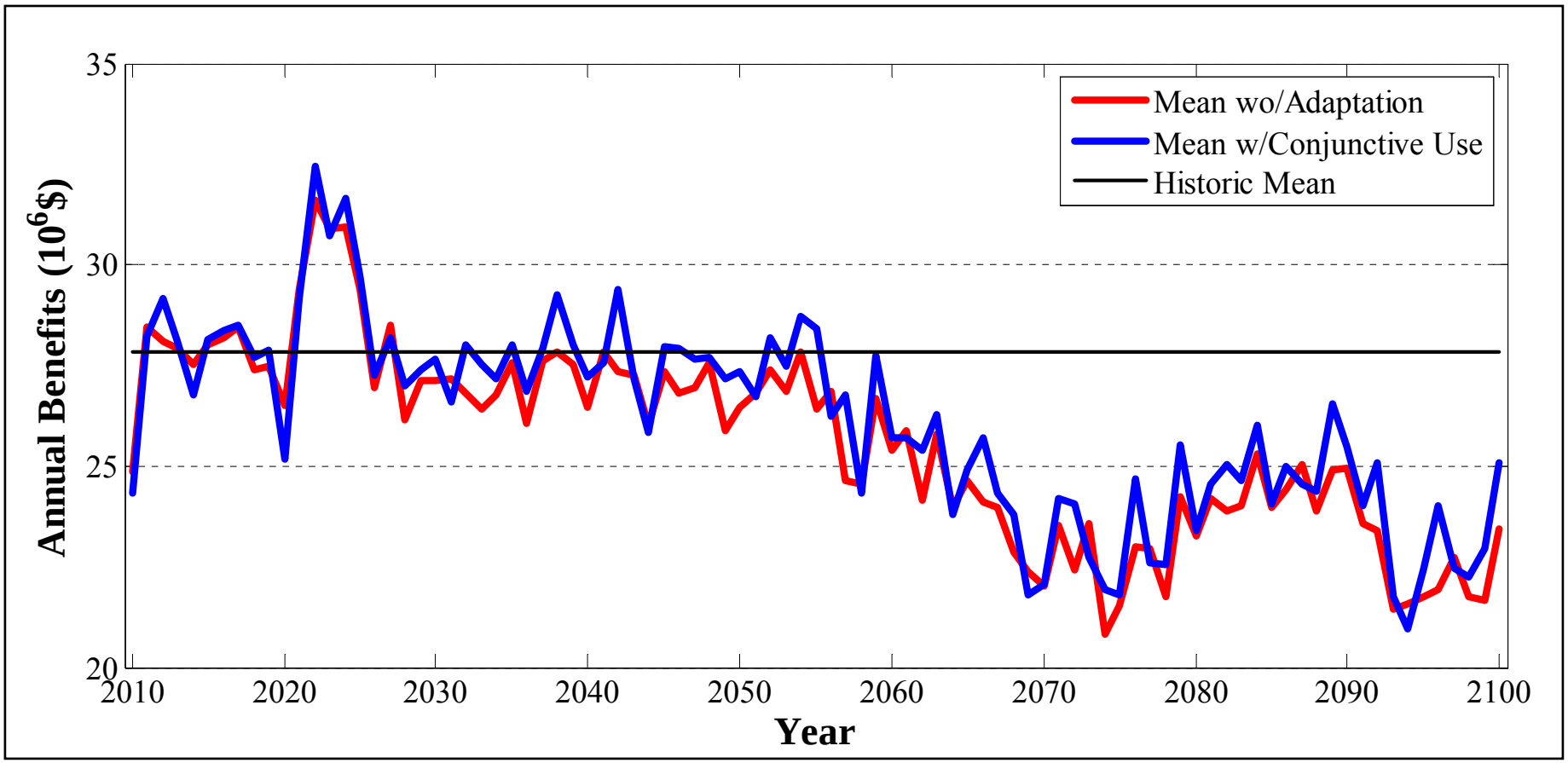


Adaptation Strategy (3): Conjunctive Use



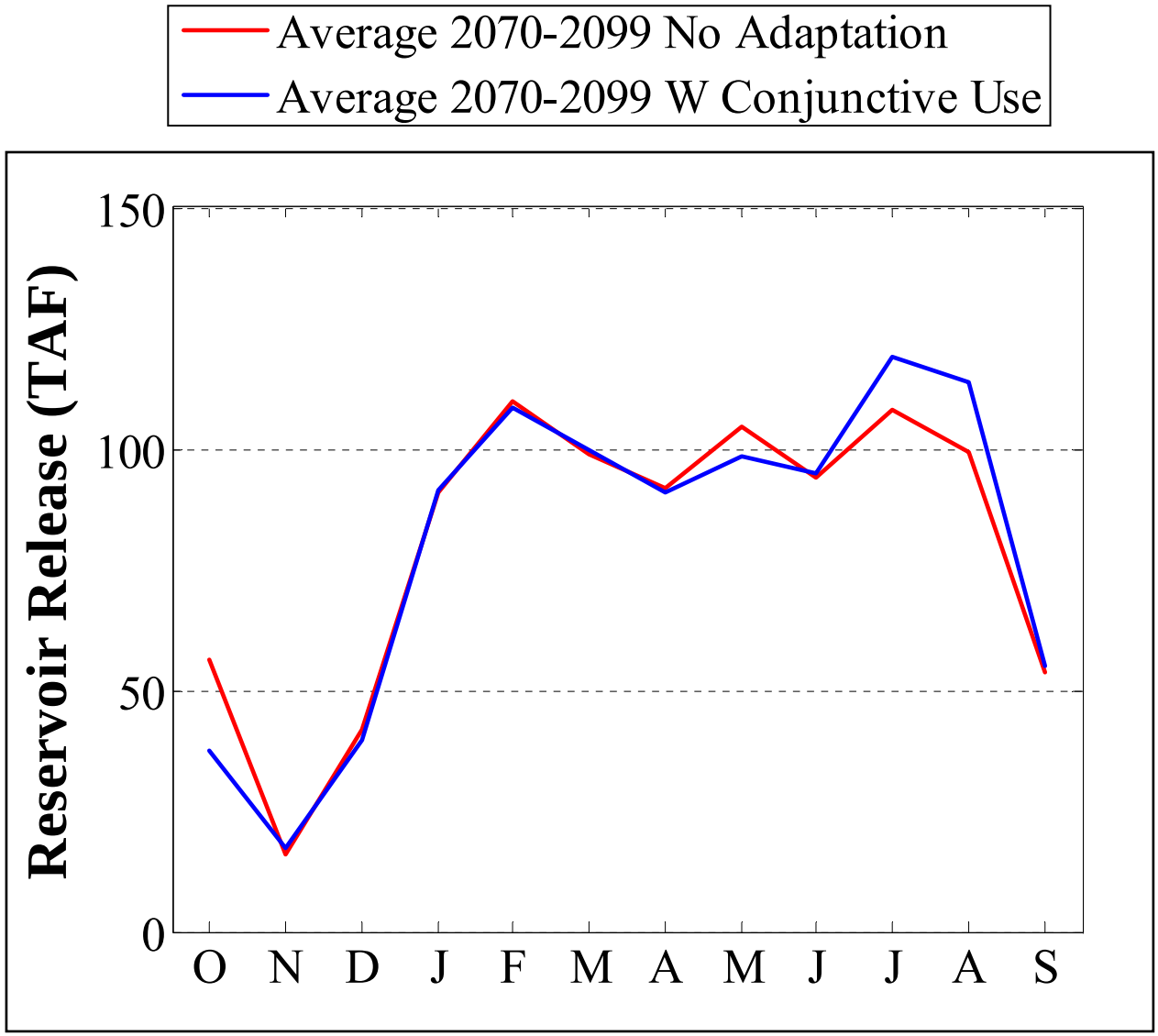
Adaptation Strategies:

Conjunctive use: both reservoir and aquifer are operated in a coordinated way

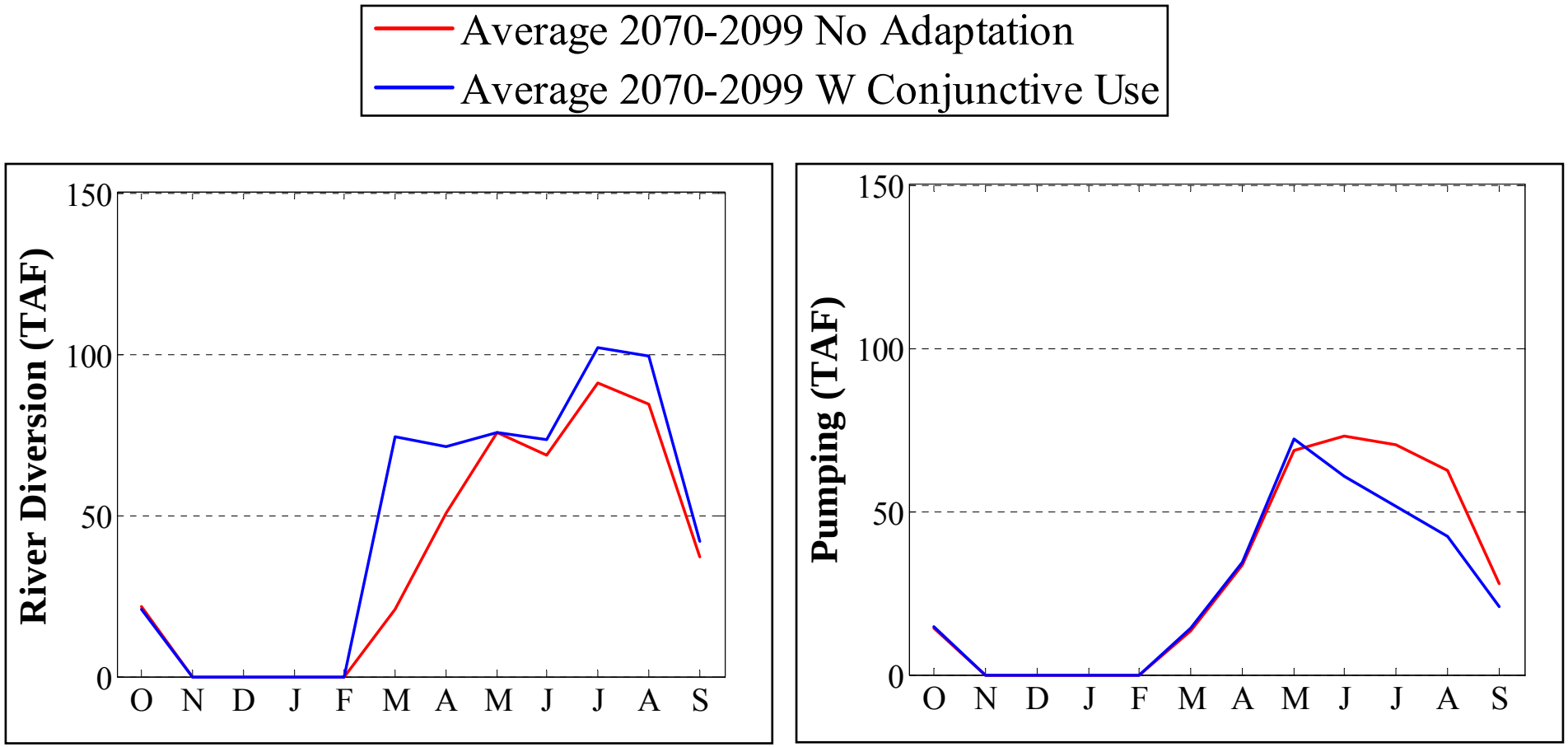


(2% Improvement over base case)

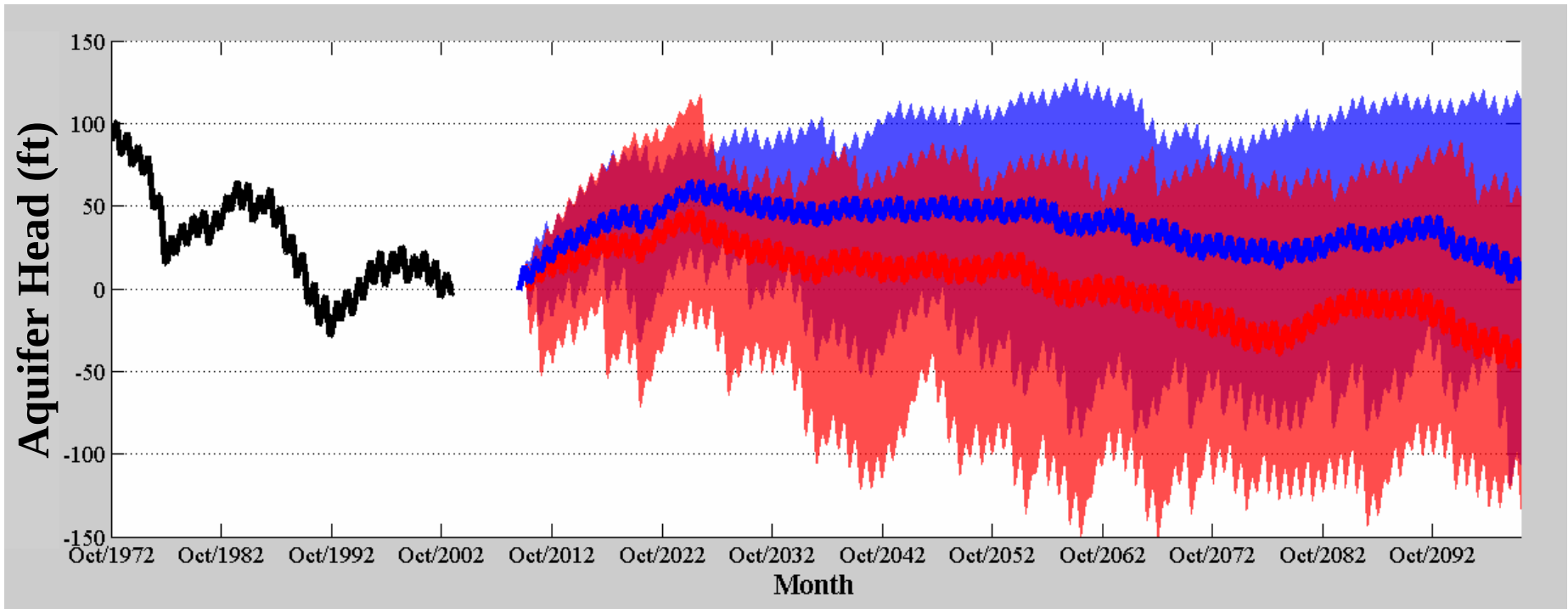
Comparison between base case and conjunctive use scenario: System operations



Comparison between base case and conjunctive use scenario: System operations



Comparison between base case and conjunctive use scenario: Groundwater level



Conclusions

- Conditions in the future will change and system operations should accommodate to these changes.
- There are some strategies that could be implemented even under the uncertainties associated with changes in precipitation
- The benefits of adopting these strategies are greater if adopted later in the 21st century
- Conjunctive use seems to be a no-regret, robust option

Future steps

- Combine conjunctive use with infrastructure modification and reservoir re-operation
- Finish my dissertation!!

Acknowledgments

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Thanks!!

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Extra slides

Approach Schematic